A report from The Pew Charitable Trusts and Audubon Florida | Nov 2013

Audubon FLORIDA

THE PEW CHARITABLE TRUSTS

Fins and Feathers:

Why Little Fish Are A Big Deal To Florida's Coastal Waterbirds

Brown Pelican
Pelecanus occidentalis

Forage Fish:

Small fish that serve as food for coastal birds, marine animals, and valuable fish species.

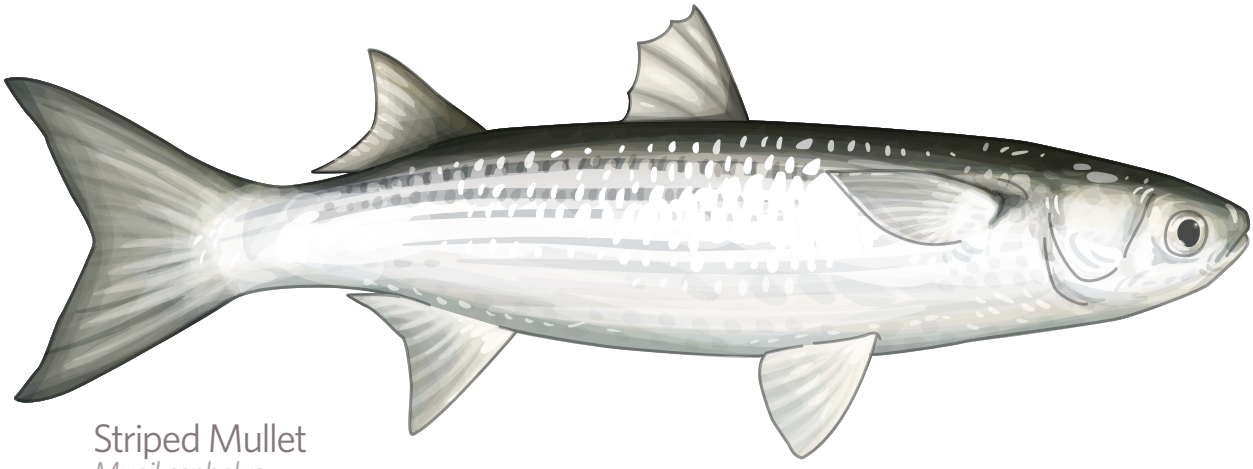
Introduction and summary

Florida's birdlife is some of the most captivating and well-recognized in the country, from impossibly pink Roseate Spoonbills to the raucous gulls and terns of our sandy beaches. Coastal waterbirds are as emblematic of our state as orange juice, yet they also serve as a sensitive bellwether for the health of the ecosystem that supports our coastal communities and economy.

At the start of the 20th century, many Florida bird species were in steep decline because of exploitation for the millinery trade. Their bright, ornate feathers were highly prized as decoration for women's hats. Most of these bird populations rebounded after the federal government banned this practice , yet today many of these birds are again threatened and decreasing. They face pressures on where they live and competition for the food they eat. Habitat loss is often the emphasis of bird conservation efforts, but comprehensive conservation of any species must consider all its vulnerabilities.

Forage fish—sometimes known as baitfish or prey fish—play a vital role in the marine ecosystem as a food source for coastal birds and other marine wildlife. These small, nutrient-rich fish are the crucial link between plankton and predators in the ocean food webs. The schooling behavior and relative abundance of forage fish make them ideal prey for much larger coastal predators such as Terns, Pelicans, and Ospreys, as well as their ocean counterparts such as tarpon, snook, and dolphins.

In this report, we investigate an area of growing concern for these birds: how declines in populations of forage fish in Florida's coastal waters could exacerbate declines of seabirds, wading birds, and other fish-eating birds, particularly species of conservation concern such as Least Terns and Black Skimmers.



Striped Mullet
Mugil cephalus

Three recent peer-reviewed studies highlight the importance of conserving forage fish for seabirds and other marine wildlife:

- **"Global Seabird Response to Forage Fish Depletion: One-third for the Birds":** A 2011 paper published in the journal Science by an international team of 14 researchers found that when forage fish biomass fell below one-third of the maximum historical level, seabird populations produced fewer chicks. Particularly notable was the finding that declines in seabird nesting success were consistent across seven marine ecosystems and 14 seabird species. This study provides guidance on the threshold of minimum forage species biomass needed to sustain seabird populations and productivity over the long term.
- **"Impacts of Fishing Low-trophic Level Species on the Marine Ecosystems":** In a paper also published in 2011 in Science, researchers used three ecosystem models in five well-studied areas to examine systemwide effects of fishing on forage species. In all the areas and across models, researchers found that fishing at the conventional goal of maximum sustainable yield (the largest average catch that can be taken continuously from a fish stock without depletion under existing environmental conditions) affects the ecosystem significantly. The researchers found that as catch rates of forage fish decreased, the harm to the ecosystem was reduced. Specifically, they found that when fishing was reduced by half, there were much smaller effects on the ecosystem, including predatory birds, and this still allowed catch of forage fish at 80 percent of maximum sustainable yield.
- **"Little Fish, Big Impact: Managing a Crucial Link in the Ocean Food Webs":** The Lenfest Forage Fish Task Force, a panel of 13 fisheries and marine scientists, spent three years conducting a comprehensive global analysis of forage fisheries. The task force surveyed the literature, held workshops, made site visits, and undertook new quantitative modeling of marine food webs. In April 2012, the scientists issued their findings, which included recommendations to fisheries managers for improving the sustainability of forage fisheries. They found that conventional fisheries management can be risky, in part because it does not capture the critical role forage fish play as prey for seabirds, marine mammals, and many species of fish targeted by fishermen. They recommended cutting catch rates by half in many ecosystems, as well as doubling the minimum biomass of forage fish left in the water, compared with conventional management targets.

The needs of predator populations such as seabirds are not considered explicitly in managing forage fish such as herring, mullet, and sardines in Florida's coastal waters. Also, prey that the state's coastal waterbirds depend upon is not well-described or considered in bird conservation efforts.

> Fewer forage fish could exacerbate declines of seabirds, wading birds, and other fish-eating birds.

Reddish Egret
Egretta rufescens

Issues in Focus:

In this report, Audubon Florida brings its bird expertise together with The Pew Charitable Trusts' marine conservation focus to:

- Explore the ecosystem connections between Florida's coastal waterbirds and forage fish.
- Assemble the best available science on the diets of coastal waterbirds found along Florida's coast and offshore waters.
- Examine the vulnerabilities of these coastal waterbirds to decreases in prey availability.

> Few rules directly limit the amount of forage fish taken out of Florida's coastal waters.

This report is especially timely given Florida's current effort to revise its Threatened Species list. The Florida Fish and Wildlife Conservation Commission has drafted management plans and supporting regulations for 60 species of conservation concern, 10 of which are birds that rely on forage fish as part of their diet. That is why our joint report concludes with four recommendations for managing forage fish in the state's coastal waters. The recommendations could help ensure that sufficient numbers of forage fish remain in coastal waters as prey for coastal waterbirds.

Recommendations:

- Explicitly account for the dietary needs of coastal waterbirds before expanding current forage fisheries or allowing the development of new fisheries.
- Ensure sufficient abundance, variety, and sizes of forage fish species to meet the needs of coastal waterbirds and other marine wildlife when setting management limits on forage fishing.
- Identify and map foraging areas for nesting coastal waterbirds and areas subject to forage fisheries, analyze potential overlap of these areas and activities, and consider conservation and management options to avoid or minimize potential conflicts.
- Protect forage fish habitat such as mangrove forests and sea grasses, as well as water quantity and quality in the estuaries.

As this analysis of the literature demonstrates, Florida's coastal waterbirds may be affected by changes in the size, seasonality, distribution, abundance, and duration of prey fish availability. Our recommendations could help ensure sufficient prey for these vulnerable species. The focus is on strategies to address fishing for forage species because this is in line with recommendations in recent peer-reviewed scientific literature, and it is an element that can be controlled directly. Reducing fishing pressure can also add resilience to forage fish populations so they are better able to avoid collapse in the face of other stressors such as red tides.

The interplay of coastal birds and forage fish in Florida

> Certainly the most deep-rooted link between birds and human values and priorities is based on an intrinsic, evolutionary-derived appreciation that people have for almost all birds. This appreciation is not limited to waterbirds, although large, showy waterbirds certainly are primary beneficiaries of these values. In general, almost all people grow up in environments where birds are part of their lives; part of the routine background sights and sounds that surround us. As a result, people consistently value these elements of their environments that bring them comfort, due to these long associations.[5]
>
> —Ornithologist John C. Ogden (1938-2012)

Florida's coastal and nearshore ecosystems drive both a vibrant marine environment and economy. The state's 2,276 miles of tidal coastline habitats span temperate and subtropical latitudes, supporting an abundance and rich diversity of coastal birds, fish, and other marine animals. Tourists from around the world have made Florida a destination for wildlife viewing.

The economic impact of visitors and residents who watched birds, dolphins, marine turtles, and other wildlife in Florida amounted to $4.9 billion in 2011. In addition, almost 1 in 5 state residents participates in wildlife viewing. Between 2006 and 2011, the number of people who visited Florida to view wildlife increased 22 percent.[6]

Ecologically, coastal birds are an integral part of the marine ecosystem, serving as both predators and prey.[7] Their feeding activities are important for redistributing nutrients between the marine and terrestrial environments,[8] including soil perturbation during foraging.[9] Similarly, forage fish provide a critical link in the ocean food web between plankton at the bottom of the web and predators at the top.[10] Many coastal breeding and non-breeding birds rely on forage fish for some part of their diet. They are largely opportunistic in their use of resources by, for example, seasonally shifting their prey preferences and foraging habitats.[11] Each species' prey is determined primarily by its foraging strategy, the size class of prey it can consume, and seasonal or periodic changes in prey availability.

Although research suggests that overall declines in forage fish could be affecting coastal waterbird populations, it is difficult to draw explicit relationships between the decline of any one prey species and one or more waterbird species. Forage fish found in Florida's coastal waters are taxonomically diverse and include species such as herring, sardines, mullet, and menhaden. They characteristically form schools and spend much of their time high in the water column or near the surface of tidal estuaries and marine waters. This makes them readily available to fish-eating birds that employ a variety of foraging strategies.

Skimmers, gulls, and frigatebirds eat prey from the water's surface, while terns, pelicans, and Ospreys plunge into the water for food. Other birds, such as diving ducks and cormorants, dive deep for prey and can exploit schooling fish found near the bottom of shallow ocean waters. Birds in the pelagic group, such as petrels and shearwaters, feed and rest offshore in deeper waters, and are rarely seen on the shore, usually only when in failing health.

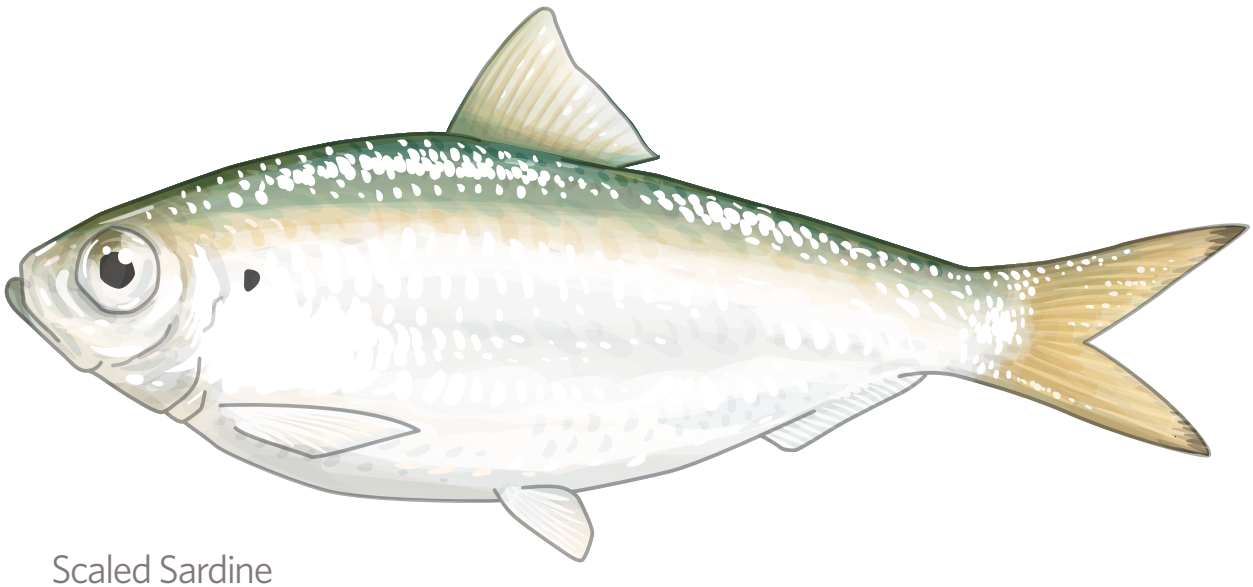
Recently, scientists correlated diminished forage fish availability with declines in seabird productivity across seven ecosystems in diverse parts of the world.[12] Sometimes, such as during nesting season, seabirds can have heightened vulnerability to scarce forage fish populations. This is because adult birds must feed themselves as well as their chicks and thus cannot range far from the nesting site in search of prey.

Fewer forage fish can result from overfishing, as well as habitat loss due to diminished estuarine flows, water quality deterioration from non-point pollution sources and red tides, loss of seagrass beds and marsh nurseries, or changes in temperature, weather, and sea level patterns. The abundance of forage fish is highly variable and often unpredictable,[13] even without the stressors mentioned above. Forage fish are also easily caught even when population numbers are low because of their schooling behavior.[13] This has led to overfishing and population collapses in many cases, especially when coupled with other environmental factors.[14]

Florida snapshot

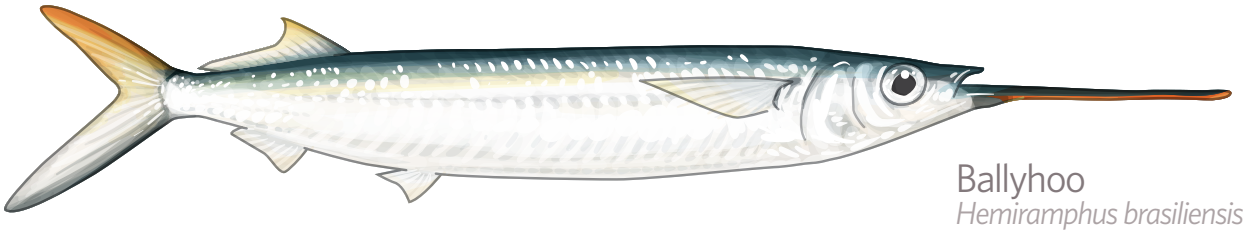
- **2,276** miles of tidal coastline habitats
- **$4.9 billion:** economic impact of wildlife viewing
- **1 in 5** Floridians who participate in wildlife viewing

Ocean fish populations are usually managed species by species, with little consideration of how catch of one population affects the ecosystem as a whole. In Florida, the state has restricted the size and types of some fishing nets that typically snare small fish. However, in October 2013, a Tallahassee circuit judge ruled that the regulations are fundamentally unfair and ordered the state to stop enforcing them. The restrictions, put into place to implement a net ban approved by voters in 1994, will stay in place while the state appeals the decision. Few other regulations directly limit the amount of forage fish—ranging from sardines to herring—that can be hauled out of Florida's coastal waters each year, and the 2012 commercial landings of seven main types of forage species made up more than one-fifth of the total commercial catch off Florida that year.[15] (See Table 1.)



Scaled Sardine
Harengula jaguana

Striped mullet is the only forage species for which a management goal has been established, but it does not explicitly consider the fish's critical role as prey.[13] Also, only striped mullet and ballyhoo have management plans drafted. The remaining forage species found in Florida's waters do not have such plans or goals in place, and there is no cap on the amount taken out of the water. This leaves them vulnerable to exploitation and could harm the coastal waterbirds, marine fish, and other predatory ocean wildlife that depend on this food source.



Ballyhoo
Hemiramphus brasiliensis

In this report, we address only coastal bird species that depend at least partly on fish, excluding taxa such as shorebirds that forage on marine invertebrates and insects or wading birds that feed in freshwater systems or on invertebrates. Table 2 summarizes a subset of imperiled coastal waterbird species with their listing status and conservation concerns. In the following section of the report, we examine in detail some representative species. Appendix A provides a more complete list of Florida's coastal waterbirds and their diets.

The designation of several species as imperiled under Florida law will change when new management plans are adopted in 2014. Both their current designation and their anticipated status in 2014 are listed in Table 2. Since official or informal moratoria have been in place on state and federal listing processes for much of this century, such designations underscore the importance of using several measures to gauge imperilment.

Table 1

Commercial Forage Fishing in Florida

Landings and Value of Forage Fish in Florida, 2012

2012 Commercial Landings and Value of Forage Fish in Florida			
Species / Category	**Total Landings[a]**	**Estimated Value[a]**	**FWC Management Goal**
Striped mullet	9,599,144 lbs.	$6,882,605	35% Spawning Potential Ratio (SPR)[b]
Sardines (Spanish and Scaled)	996,830 lbs.	$254,109	None
Baitfish[c]	1,890,877 lbs.	$581,167	None
Industrial fish (e.g. shad, alewife, herring, sardine, menhaden)[d]	2,120,844 lbs.	$234,741	None
Ballyhoo	797,439 lbs.	$459,941	None
Scad (Round—also called cigarfish and Bigeye—also called "goggle eye")	387,805 lbs.	$492,725	None
Atlantic thread herring	1,707,630 lbs.	$239,849	None
TOTAL	**17,500,569 lbs.**	**$9,145,137**	**N/A**

Note:

a Florida Fish and Wildlife Conservation Commission, Commercial Landings database, last revised 08/13/13. This table lists most, but not all, major forage species caught in Florida state waters in 2012.

b Florida Fish and Wildlife Conservation Commission, Striped Mullet Agenda Document, 2008. Spawning Potential Ratio, or SPR, is defined as the current number of spawning adults in a population compared with the number of spawning adults that would be found in that population if there was no fishing for that species.

c Baitfish are caught and sold commercially for use as bait and can include a variety of species.

d Industrial fish include any Clupeiformes and are primarily used for pet food and fish meal, and as chum. Steve Brown, personal communication, Florida Fish and Wildlife Conservation Commission, April 17, 2012.

Table 2

A Snapshot of Imperiled Florida Coastal Waterbirds

Florida listed bird species that eat marine forage fish, their protected status, and current conservation concerns

Species	Listed Status	Conservation Considerations
Black Skimmer	Species of Special Concern (Florida 2013); Threatened (Florida 2014); Regional and Continental Concern[a]; Yellow[b]	Reduced population and colony sizes.[c]
Brown Pelican	Species of Special Concern (Florida 2013); delisted (Florida 2014)	Although populations have increased in the past three decades, recent declines have been demonstrated in South Carolina.[d]
Least Tern	Threatened (Florida 2013 and 2014); Regional and Continental Concern[a]; Red[b]; Endangered (Great Plains and California populations only, U.S. Fish and Wildlife Service, USFWS)	For lack of sufficient habitat, 80% of Florida's Least Terns nest on gravel rooftops, which are disappearing[e]
Roseate Tern	Threatened (Florida 2013 and 2014); Threatened in Florida (USFWS); Regional and Continental Concern[a]	Loss of nesting sites in the Florida Keys has brought precipitous declines in the only breeding population in the continental U.S.[a]
Little Blue Heron	Species of Special Concern (Florida 2013); Threatened (Florida 2014)	Species has gradually declined in Florida since the 1990s.[f]
Reddish Egret	Threatened (Florida 2013 and 2014); Regional and Continental Concern[a]; Red[b]; Near Threatened[g]	Current population is 10% of its size before being decimated by plume hunting.[h]
Roseate Spoonbill	Species of Special Concern (Florida 2013); Threatened (Florida 2014); Local and Regional Interest[a]	Fewer than 1,500 pairs remain in Florida, with the population characterized as small and geographically restricted.[i]
Magnificent Frigatebird	Regional and Continental Concern[a]; Red[b]	Low-flying disturbance from tourist planes on the Marquesas before 1990 might have been the cause for the frigatebird colony's relocation to its current site at Dry Tortugas National Park, near Key West.[a]
Black-capped Petrel	Continental and Regional Concern[a]; Red[b]; Candidate species for listing (USFWS)	USFWS was petitioned to list the Black-capped Petrel as Endangered. It awarded the species Candidate status while under consideration in 2012.
Greater Shearwater	Continental Concern[a]; Yellow[b]	Necropsies during the 2002-03 seabird die-off on the Atlantic coast were "most consistent with 'Emaciation Syndrome,' which may involve dramatic change in mean water temperatures that affect food fish availability, leading to physiological stresses and starvation."[a]

Note:

a William C. Hunter et al., Southeast United States Regional Waterbird Conservation Plan, 2006, http://www.waterbirdconservation.org/pdfs/regional/seusplanfinal906.pdf.

b Gregory S. Butcher et al., "The 2007 WatchList for United States Birds," American Birds 2006-2007, Summary of the 107th Christmas Bird Count, 2007, pp. 18–25, http://wa.audubon.org/documents/american-birds-107-2007-watchlist-united-states-birds-gregory-s-butcher-daniel-k-niven-arv. RED: species in this category are declining rapidly and/or have very small populations or limited ranges, and face major conservation threats. These typically are species of global conservation concern. YELLOW: this category includes species that are either declining or rare. These typically are species of national conservation concern.

c Florida Fish and Wildlife Conservation Commission, Black Skimmer Biological Status Review Report, 2011. http://myfwc.com/media/2273268/Black-Skimmer-BSR.pdf

d Florida Fish and Wildlife Conservation Commission, Brown Pelican Biological Status Review Report, 2011. http://myfwc.com/media/2273274/Brown-Pelican-BSR.pdf

e Florida Fish and Wildlife Conservation Commission, Least Tern Biological Status Review Report, 2011. http://myfwc.com/media/2273337/Least-Tern-BSR.pdf

f Florida Fish and Wildlife Conservation Commission, Little Blue Heron Biological Status Review Report, 2011. http://myfwc.com/media/2273343/Little-blue-heron-BSR.pdf

g IUCN, IUCN Red List of Threatened Species, Version 20, 2012, www.iucnredlist.org.

h Florida Fish and Wildlife Conservation Commission, Reddish Egret Biological Status Review Report, 2011. http://myfwc.com/media/2273367/Reddish-egret-BSR.pdf

i Florida Fish and Wildlife Conservation Commission, Roseate Spoonbill Biological Status Review Report, 2011. http://myfwc.com/media/2273376/Roseate-Spoonbill-BSR.pdf

Least Tern
Sternula antillarum

The coastal waterbirds of Florida

For this report, we have grouped coastal birds according to their common foraging habits, geographic similarities, and the seasons in which they forage in Florida, providing examples of waterbirds in each category. A more complete list of bird species and their forage fish prey can be found in Appendix B.

Coastal waterbirds breeding in Florida

Breeding birds are especially dependent upon reliable and abundant prey availability near nesting sites in order to raise their young. Several of these species remain in Florida through the winter; others migrate to Latin America.

Seabirds breeding in peninsular Florida

The success of bird colonies breeding coastally around the Florida mainland might be correlated to local prey abundance. Such species are: Least Tern, Black Skimmer, Royal Tern, Sandwich Tern, Caspian Tern, Gull-billed Tern, Laughing Gull, Brown Pelican, and Double-crested Cormorant. Least Tern, Black Skimmer, and Brown Pelican typify this group of coastal waterbirds.

Least Tern
Sternula antillarum

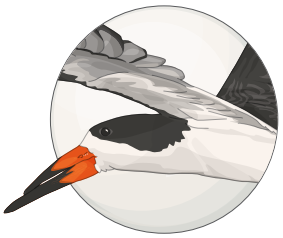
Least Terns (*Sternula antillarum*) nest in colonies, often with Black Skimmers, predominantly in coastal areas. They forage in nearshore marine waters, tidal estuaries, and coastal marshes. Additionally, there is limited nesting and foraging near inland freshwater lakes.[16]

Least Terns feed their chicks live fish. Because chicks swallow the fish whole, the parents must bring tiny fish to younger chicks. Therefore, during chick-rearing time, Least Terns not only need abundant prey but also a variety of prey sizes capable of feeding the adults as well as growing young birds of varying size.

The terns catch their prey by shallow plunge-diving. Their prey base is composed of small, near-surface fish including sand lance, herring, hake, anchovy, menhaden, silversides, smelt, mosquito fish, and other species.[17] Crustaceans, marine worms, and insects constitute a minor percentage of prey, which varies seasonally and geographically.

All three subspecies of Least Terns are of conservation concern. The California subspecies and the Interior subspecies are listed as federally Endangered. The Atlantic Coast subspecies is listed as threatened in every state in which it nests. In Florida, it is state-listed as threatened. Although Least Terns in the past were affected by the plume trade, nowadays threats include loss of nesting habitat and increased disturbance by humans. A California study found that reduced prey availability for breeding colonies was related to decreased mean clutch size and chick body weights, increased incidence of egg abandonment, and non-predation chick mortality.[18]

Black Skimmer
Rynchops niger



Black Skimmer
Rynchops niger

The Black Skimmer (*Rynchops niger*), with its bold black and white pattern and odd profile, is the only bird in the world with the lower half of its bill longer than the upper half. Chatty flocks of Black Skimmers delight Florida beach visitors. At dusk, these birds skim slowly over water only inches deep. They appear to trace a line as they trail their lower bill along the water's surface until they feel a fish and snatch it. In the spring and summer, the spectacle of nesting colonies attracts locals, tourists, and nature photographers. Chicks bolt out of their shallow nest "scrapes" in the sand and flap their tiny wings when a parent flies in with a fish dinner.

Black Skimmers are a colonial species, nesting on both Gulf and Atlantic beaches. The Florida resident population is augmented in winter by birds migrating from farther north.[19] Skimmers mainly feed in the calm tidal waters of bays, estuaries, lagoons, rivers, salt marsh pools, creeks, and ditches, during lower tide cycles, at dawn and at dusk.[20] The Skimmer prey base is principally small fish (5 to 12 centimeters, or 2 to 5 inches) supplemented with shrimp. Species include mullet, menhaden, needlefish, killifish, silversides, and anchovies.

The Black Skimmer is currently listed as a Species of Special Concern in Florida and will be classified as Threatened in 2014 when the state's imperiled species list is updated. The Black Skimmer's diet is generally less diverse than that of other seabirds.[21] Thus, it is likely more affected when some of its major prey species decline than birds which are diet generalists.

A research study in Virginia suggested that food supply influences the Skimmer's productivity.[22] As with the Least Tern, loss of habitat and increase in disturbances have historically been the primary concern; however, efforts must be made to ensure a sufficient prey base year round.

Brown Pelican
Pelecanus occidentalis

Brown Pelicans (*Pelecanus occidentalis*) had almost disappeared along the Gulf Coast by the 1960s and were extirpated historically in Louisiana. In 1970, they were listed by the federal government as Endangered. Since then, the ban on the pesticide DDT and stronger protection measures have helped their populations recover to the point that they were federally delisted in 2009; the Florida Fish and Wildlife Conservation Commission is removing them from the state imperiled species list in 2014.

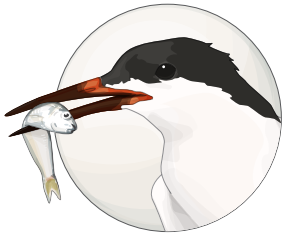
While foraging, Brown Pelicans plunge dive from 30 feet or more in the air, diving three to six feet deep headfirst into the water to catch fish. When they surface, they throw their heads back to swallow the catch. Brown Pelicans

feed and roost together, and nest in colonies. Groups of Brown Pelicans are often seen flying low, just over the waves, or high in the air in loose formation.

Their diet consists almost entirely of small, surface-schooling fish, predominantly menhaden and mullet, although they eat some crustaceans. Additional prey species in the Gulf of Mexico and Caribbean include anchovies, herring, sailfin mollies, dwarf herring, and sardines.[23] On Florida's Gulf Coast, Brown Pelicans are known to eat menhaden, silversides, mahi, and prawns,[24] with nestlings consuming menhaden, mullet, Atlantic threadfin, sea trout, spot, pinfish, sardines, and bay anchovy.[25] Mullet have been noted as a dominant food item for Brown Pelicans in Florida Bay.[26] Anecdotal reports in Florida of young pelican mortality, especially during cold winters, remain understudied and of concern.

Seabirds breeding only in the Florida Keys

Because of their geographically restricted breeding and generally lower abundance, these species can be particularly sensitive barometers of diminished prey availability and other threats near their breeding sites. Yet they also tend to range widely outside their breeding season and can seek prey in other locales if the availability is poor locally. These species include Roseate Tern, Magnificent Frigatebird, Sooty Tern, Bridled Tern, Brown Noddy, and Masked Booby. The Roseate Tern typifies this group.



Roseate Tern
Sterna dougallii

Roseate Terns (*Sterna dougallii*) breed in both temperate and tropical areas. The worldwide breeding range of this species is fragmented[27] into small, isolated breeding populations. Roseate Tern populations in Europe and Africa have declined to critically low levels. In northeastern North America, they are listed as Endangered; Roseate Terns from Florida to North Carolina, Puerto Rico, and the Virgin Islands are listed as Threatened.

In Florida, Roseate Terns' nesting is limited to beaches and flat gravel rooftops in the Keys. They mostly feed on fish and are more specialized than other species of terns. In Puerto Rico, prey consists mainly of dwarf herring, anchovies, and sardines.[28] In the Northeast, sand eels also figure prominently in their diet.[29]

Like several other species of seabirds, Roseate Terns often fish close to pelicans, marine mammals, or predatory fish that herd small prey fish and bring them close to the surface, making them easier to catch. A study of breeding Roseate Terns in Puerto Rico found that they are more dependent on feeding over pelicans and predatory fishes than other terns.[30]

Roseate Tern
Sterna dougallii

Wading birds

Wading birds nest and forage in both fresh- and saltwater environs in Florida. Species that feed on marine forage fish include Reddish Egret, Great Egret, Snowy Egret, Great Blue Heron, Little Blue Heron, Green Heron, Black-crowned Night Heron, and Roseate Spoonbill. The Reddish Egret and the Roseate Spoonbill are representative of these wading birds.

Reddish Egret
Egretta rufescens

The Reddish Egret (*Egretta rufescens*) once was one of the most abundant species of herons in Florida, but it is now the rarest. The population suffered huge losses during the plume trade in the late 1800s and early 1900s. Although the population increased in the 20th century after the ban on hunting them was implemented, it is currently estimated at 10 percent of the population size before plume hunting, with an estimated 350 to 400 pairs statewide as of the early 1990s.[31]

Reddish Egrets are easily recognized by their active hunting behavior. In contrast to other herons and egrets, which stand still in the water waiting for prey to approach, Reddish Egrets pursue their prey. Their seemingly erratic hunting behavior is best described as giving the appearance that they had too much to drink! This behavior and their bi-colored beaks are useful for recognizing both dark morph and white morph Reddish Egrets (some are born with all white feathers and resemble Great Egrets).

Reddish Egrets forage primarily on nearshore, marine flats in water 2 to 6 inches deep. Small fish in these shallow depths comprise most of their prey, along with some crustaceans. In Florida Bay, Reddish Egrets forage on a variety of fish species, primarily sheepshead minnow, sailfin molly, gold-spotted killifish, and marsh killifish.[32] Although other herons often feed in fresh water, the Reddish Egret feeds primarily in brackish and salt water, possibly making it more reliant on adequate supplies of marine and estuarine forage fish than other egrets.

Roseate Spoonbill
Platalea ajaja

The Roseate Spoonbill (*Platalea ajaja*) never goes unnoticed: spectacular pink plumage accented by a red stripe on the wing, an orange tail, and a peculiar flattened bill with a spoon-shaped end that gave the bird its name. Lines of cars parked along the road often indicate a pond where a group of them is feeding, motorists snapping pictures and calling friends to report a flock of "flamingos."

Roseate Spoonbill populations were reduced to 15 nesting pairs toward the end of the plume-trade era in the early 1900s, but the numbers grew after legal protections and enforcement of conservation areas were in place.[33] Roseate Spoonbills are tactile foragers and seek prey by moving their bill from side to side in the water. Stomach-content analyses have revealed mostly small fish.[34] In Florida Bay, they primarily eat sheepshead minnows, sailfin mollies, marsh killifish, and sunfish, in addition to small shrimp.[35]

Spoonbills must have abundant prey in relatively shallow water to feed their young. Chick rearing is timed with the Florida dry season. Lower water levels in wetlands help concentrate the prey fish, allowing the adults to catch plenty of them and to raise two to four chicks per nest. Draining, ditching, pumping, and other modifications of the natural water flow to Florida estuaries alter the water quantity in wetlands where spoonbills feed. Too much water means that prey fish are not concentrated enough for the birds to catch, so the chicks might starve.

Fish-eating birds of prey

These species breed near and forage in both fresh-water and marine habitats in Florida. The species include Osprey and Bald Eagle. The Osprey typifies this group of birds.

Osprey
Pandion haliaetus

Ospreys (*Pandion haliaetus*) are amazing raptors evolved to catch fish. Their feet have a reversible outer toe that lets them grab their prey with two toes in the front and two in the back. They also have barbed pads on the soles of their feet that help them hold onto their prey. Several studies show that Ospreys catch fish on at least one in four dives, and are sometimes successful as often as 3 out of 4 dives. They take an average of just 12 minutes to catch their prey fish.

The diet of these very successful predators[36] consists almost exclusively of live fish, taking species in relation to their availability and food value.[37] In Florida, their prey includes striped and white mullet, gafftopsail and hardhead catfish, jacks, spotted sea trout, pinfish, filefish, and sheepshead porgy.[38] In other parts of North America, Ospreys have been reported consuming primarily surf perch (California),[39] winter flounder (New York),[40] and alewife, smelt, winter flounder, and pollock (Nova Scotia).[41]

In times of scarce food, nesting success may decline for many birds because their eggs hatch over a period of days rather than all at once. This means older hatchlings can monopolize the food brought to the nest leaving younger chicks to starve.

Greater Shearwater

Puffinus gravis

Passage or overwintering coastal waterbirds

Some bird species breed elsewhere but depend upon Florida habitats for stopovers on their migrations, or as their wintering grounds. During migration, the birds must rest and feed to store enough fat to complete their journey and arrive in good health on their breeding grounds. These waterbirds include what are known as pelagic-foraging species, which spend most of their lives feeding and resting on the open ocean, and gulls and terns that spend the winter in Florida.

Penguins in Florida?

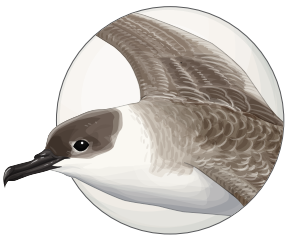
In December 2012, state wildlife officials began receiving reports of "penguins" in Florida waters from casual observers along the Atlantic coast. Upon closer inspection, the sightings were not of penguins, but their Northern Hemisphere look-alike, Razorbills.

Razorbills (*Alca torda*) are, like puffins, members of the alcid family. Before 2012, fewer than 20 historic records of Razorbill sightings in Florida existed, but during the 2012-2013 winter they were spotted in the thousands. These small seabirds ordinarily breed on the coasts of Canada and Maine, wintering as far south as New England. Nearshore turbidity due to Superstorm Sandy was first hypothesized as the cause, but alcid specialists now suspect that changes in sea surface temperatures affected the birds' prey availability in their normal range, driving them south in search of winter prey.

This extraordinary movement of near-arctic birds could illustrate the vulnerability of bird populations to declines in prey fish availability, as well as the hemispheric importance of abundant local forage fish.

Pelagic-foraging species

Offshore waters are feeding grounds for some species during their time in Florida. These locations are often in federally-managed waters, which extend more than three miles offshore on the east coast, and more than nine miles from Florida's Gulf coast. Species include Northern Gannet, White-tailed Tropicbird, Black-capped Petrel , storm-petrels, Audubon's and Greater Shearwaters. Greater Shearwaters are typical of the group.



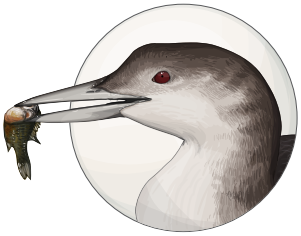
Greater Shearwater
Puffinus gravis

Flocks of Greater Shearwaters (*Puffinus gravis*) forage in pelagic waters off Florida's coastline during their hemispheric migrations. Shearwaters plunge-dive for prey at depths of up to about 6 1/2 feet but some can pursue prey up to about 65 feet deep in the water column.[42] Cephalopods, primarily squid, supplemented with fish and crustaceans comprise the majority of their poorly known diets both in breeding colonies of the South Atlantic Ocean and during northward migration.[43] Fish species identified in stomachs of dead birds washed ashore during migration along the South American coast included drums, croakers, toadfishes, and cutlassfishes.[44]

Periodic die-offs of Greater Shearwaters have been reported off Florida's Atlantic Coast, with the birds usually found to be emaciated. These events occur mostly just after the birds' breeding season, in late June. One published study suggests climate change could be contributing to this trend.[45] Better understanding of the causes of such die-offs and how to remedy them would be beneficial, especially in a state such as Florida, where the economy depends so heavily on beach tourism. Large numbers of dead birds on the beach worry both tourists and residents, and render the beach less appealing.

White Pelicans and duck-like birds

These species paddle on the surface of Florida nearshore waters, either dipping prey from the surface or diving and swimming underneath the surface. Species include White Pelican, Red-throated and Common Loons, Hooded and Red-breasted Mergansers. The Common Loon represents this group of birds.



Common Loon
Gavia immer

Common Loons (*Gavia immer*) are known for their soulful, flute-like calls on the Northern freshwater lakes where they breed. They visit Florida in the winter, foraging in nearshore marine environments in migration and winter.

Through the years, several episodes of larger-than-usual mortality events have been reported in Florida, most recently in the winter of 2012. A study published in 1997 found that the most commonly recognized problem was emaciation syndrome.[46] It is unclear why the birds are found emaciated, since many factors are in play. Abundance and availability of prey are often mentioned as possible causes.

There are no published studies of Common Loon diets in Florida. Based on studies elsewhere along the U.S. Atlantic coast during migration—and given that Common Loons, propelled by their feet, hunt prey underwater—they are expected to forage on menhaden, croaker, spot, and silversides. Large prey items that are difficult to swallow underwater, such as crabs, flounder, and lobster, also are food sources in winter.[47]

Because mortality occurring on a bird's wintering grounds affects the general health of the population, research and conservation efforts should include non-breeding grounds. In Florida, there are no good estimates of the population of wintering and passage species, making it hard to assess whether increased winter mortality is due to a larger number of wintering birds in Florida's nearshore waters, or if more birds are dying.

Wintering gulls and terns

Marine and large lake habitats are winter homes and foraging sites for species including Ring-billed, Herring, Bonaparte's, Lesser Black-backed, and Great Black-backed Gulls, as well as Forster's, Black, and Common Terns. Here, we feature Herring Gull as an example.

Herring Gull
Larus argentatus

Herring Gulls (*Larus argentatus*) do not breed in Florida, but they are a regular sight along our coastline even in summer, since some immature gulls, too young to nest, do not migrate north with breeding adults. They are large, predatory birds that eat marine invertebrates, fish, insects, and other seabirds, including the adults, eggs, and young of other gulls and terns. A study in the Great Lakes region during the non-breeding season shows forage fish as part of their diet.[48] Herring Gulls also are scavengers.

As for some other gull species, studies show a switch from a generalist diet to fish during parts of young-rearing time. On the Dutch Frisian Islands, a study reports a decrease in Herring Gull breeding success related to a decline in marine fish in the diet, due to increased competition with Lesser Black-backed Gulls.[49] This is one example of ecosystem complexity: even a minor change can have profound consequences affecting different reactions in various species, with some being more adaptable than others.

Black-Capped Petrel

Pterodroma hasitata

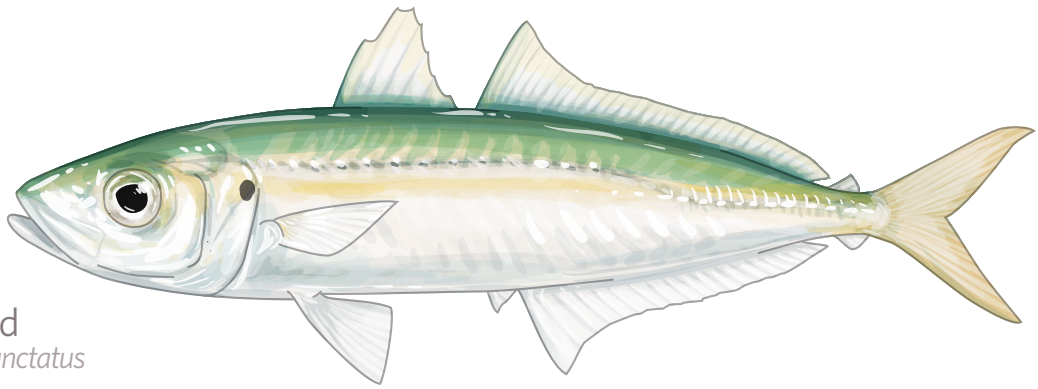
Conservation at a critical juncture

This report is especially timely given the State of Florida's current efforts to restructure its Threatened Species list. Revisions underway include preparing management plans for essential species and supporting regulations for 60 species of conservation concern, 10 of which are birds that rely on forage fish for part of their diet. Additionally, the U.S. Fish and Wildlife Service is considering federal Endangered Species Act listed status for the Black-capped Petrel, a Caribbean breeder that forages in federally managed waters off Florida's Atlantic coast.

In addition to their crucial role as prey for coastal water birds and other marine wildlife, forage fish are caught for use as bait, food, and commercial products ranging from fertilizer to fish meal. Worldwide demand is growing. Aquaculture has become the fastest growing segment of the world's food production, increasing more than 6 percent annually since the 1990s.[50] Such growth has driven up the demand—and the economic incentive—for forage fish. These small species already account for about 37 percent of global fish production, and most of it goes to fish meal and fish oil for aquaculture or agriculture feed.[51] The U.S. government has encouraged the development of offshore aquaculture in an effort to counteract the trade deficit from farmed seafood imports, calling for a five-fold increase in domestic aquaculture development by 2025.[52] The Gulf of Mexico Fishery Management Council has also adopted a plan for handling aquaculture permits,[53] another sign that the industry is likely to expand in the southeast. In 2012, seven main types of forage species, including sardines, scads, herrings, ballyhoo, and mullet, accounted for 20 percent of all commercial catch off Florida. Commercial fishermen caught more than 9 million pounds of mullet that year, mostly for their eggs, which are sold around the world. People from Taiwan to Europe are taking a growing interest in Florida mullet eggs as a delicacy and even an aphrodisiac. In Italy, mullet roe sacs are the seafood equivalent of prosciutto. Once dried and cured into *bottarga*—a phenomena that has garnered attention on NBC's Today show[54] and the *New York Times*,[55] the product can sell back in the United States for more than $100 a pound.[56]

Few regulations limit the amount of forage fish such as sardines and herring that are hauled out of Florida's coastal waters each year. Although the state has restricted the size and types of some fishing nets that typically snare small prey fish like mullet, a Tallahassee circuit judge ruled in October 2013 that the regulations are fundamentally unfair, ordering the state to stop enforcing them.[57] The restrictions—intended to implement a net ban approved by voters in 1994—will remain in effect while the state appeals the decision.

The Florida Fish and Conservation Commission should look at steps taken by other state and federal officials to account for the wider role of forage fish as a major prey base in marine and estuarine ecosystems, including their relationship to coastal waterbirds. In November 2012, the California Fish and Game Commission voted to adopt a forage fish conservation policy. When implemented, it will prevent the development of new fisheries for forage species and the expansion of current forage fisheries until essential fishery information needed for ecosystem-



Round Scad
Decapterus punctatus

Roseate Spoonbill
Platalea ajaja

based management is available and applied. The goal is to ensure the sustainability of target forage species and protection of their benefits as prey.[58]

Also in 2012, the Atlantic States Marine Fisheries Commission (the body that manages interstate fisheries within 3 miles of shore along the U.S. East Coast) established a cap on the catch of menhaden that will reduce the annual quota by 20 percent when compared with the average landings since 2009. One of the cited reasons for this cap was to increase menhaden's availability as prey for other species.[59]

Forage Fish Commonly Found in Florida's Coastal Waters

Mullet	Ballyhoo	Herring	Pinfish	Silversides
Sardines	Scad	Menhaden	Anchovies	

Recommendations

We recommend the following four actions to conserve forage fish populations in state waters and to protect coastal waterbirds that may be vulnerable to reductions in prey fish:

- Explicitly account for the dietary needs of coastal waterbirds before expanding current forage fisheries or allowing the development of new fisheries.
- Ensure sufficient abundance, variety, and sizes of forage fish species to meet the needs of coastal waterbirds and other marine wildlife when setting management limits on forage fishing.
- Identify and map foraging areas for nesting coastal waterbirds and areas subject to forage fisheries; analyze potential overlap of these areas and activities; and consider conservation and management options to avoid or minimize potential conflicts.
- Protect forage fish habitat such as mangroves and seagrass beds, as well as water quantity and quality in the estuaries.

Consider the forage needs of coastal waterbirds

The Florida Fish and Wildlife Conservation Commission should adopt a policy to ensure the forage needs of coastal waterbirds are met before expanding current forage fisheries or allowing the development of new ones. This will help ensure the sustainability of forage fish populations and the avian predator populations they support.

With nearly half of the world's seabirds in decline,[60] it seems prudent to look to other parts of the world where over-exploitation of forage fish has been correlated with seabird declines. In particular, Dr. Philippe M. Cury and his colleagues[61] suggest that a threshold of 30 percent reduction in prey populations can tip seabird populations into steep decline. These researchers recommend leaving "one-third for the birds" as an important consideration when allocating "natural harvest" in fisheries management.

Ensure an abundance of forage fish

The Florida Fish and Wildlife Conservation Commission should ensure a sufficient abundance of forage fish by managing these fisheries to leave sufficient variety of prey fish of various sizes to meet the needs of seabirds,

wading birds, and other marine wildlife. Coastal waterbirds are largely prey generalists, but their requirements for food of sufficient abundance,[62] and in particular size classes to feed to flightless young, are specific.[63]

In addition, a diversity of forage fish species and a diversity of sizes is important because the foraging methods of coastal waterbirds vary in the water depths at which they forage, in the distance from shore, in the size class of prey needed by adults versus growing chicks, and more.

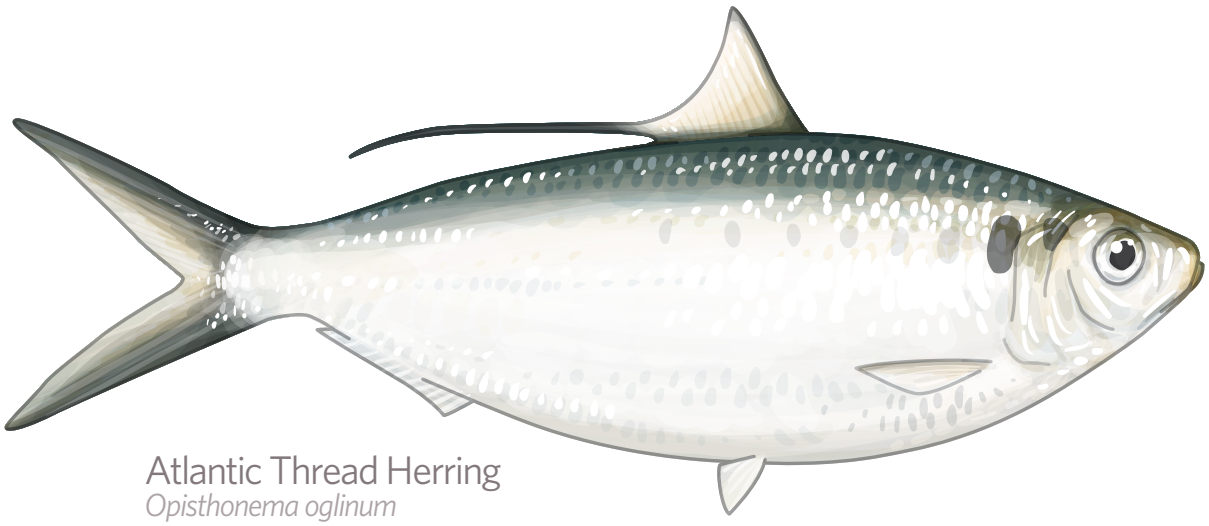
Map coastal bird foraging areas and fisheries to identify and minimize conflicts

The Florida Fish and Wildlife Conservation Commission should consider the foraging ranges of nesting coastal waterbirds and geographic extent of forage fisheries, to identify and minimize the potential impact to these declining species. The number of Florida's seabird and coastal wading bird colony sites has dropped in recent decades, and those that remain face many challenges.[64] Nests are more vulnerable to failure when local prey is scarce because adults need to forage closer to the colony in order to protect and nourish young and because chicks often require smaller size classes of prey.[65]

Colony declines attributable to diminished prey availability would warrant specific management interventions.

Protect forage fish habitat from further degradation by protecting seagrasses, mangroves, and by supporting estuary health

Florida's patterns of coastal development have directly affected seagrass beds, mangrove forests, and salt marshes, which serve as critical nursery habitat for pelagic fishes. Similarly, changes in the quantity, quality, and timing of freshwater delivery to estuarine systems have degraded the quality and diminished the extent of these habitats. In 1999, for example, Jerome J. Lorenz, an Audubon researcher at the Tavernier Science Center in Tavernier, FL, demonstrated that prey fish productivity is related to water levels and salinity (i.e., freshwater flow) in the southern Everglades.[66] In 2013, Lorenz demonstrated the connection between water levels, prey availability, and the nesting success of Roseate Spoonbills.[67] To avoid further habitat degradation and to safeguard the prey base upon which coastal waterbirds depend, state and federal land-use regulators and water managers should ensure no additional direct loss of these habitats. Additionally, water management plans must at least exceed the state-mandated Minimum Flows and Levels Criteria for each estuarine system and ensure that sufficient water is reserved for environmental health.



Atlantic Thread Herring
Opisthonema oglinum

Little Blue Heron
Egretta caerulea

Magnificent Frigatebird
Fregata magnificens

Authors

Holly Binns
Monique Borboen
Marianne Korosy Ph.D
Shawn E. Clem Ph.D
Jerome J. Lorenz Ph.D
Aaron Podey
Julie Wraithmell

Acknowledgements

This report benefited tremendously from the expert peer reviews of Dr. Elizabeth Forys (professor of Environmental Science and Biology, Eckerd College), Roy O. Williams (formerly of the Florida Fish and Wildlife Conservation Commission's Division of Marine Fisheries Management) and a reviewer who asked to remain anonymous. Support for the research, writing and production of this report was provided by The Pew Charitable Trusts.

For further information, please visit:

fl.audubon.org pewenvironment.org

Contact: Julie Wraithmell
Phone: 850-222-2473 (BIRD)
Email: jwraithmell@audubon.org

Contact: Holly Binns
Phone: 850-322-7845
Email: hbinns@pewtrusts.org

The Pew Charitable Trusts is driven by the power of knowledge to solve today's most challenging problems. Pew applies a rigorous, analytical approach to improve public policy, inform the public, and stimulate civic life.

Now in its second century, **Audubon** connects people with birds, nature, and the environment that supports us all. Our national network of community-based nature centers, chapters, scientific, education, and advocacy programs engages millions of people from all walks of life in conservation action to protect and restore the natural world.

Appendix A. Recommendations for further investigation

Although the existing body of general scientific literature suggests important links between the availability of forage fish and Florida's coastal waterbird populations, additional research in Florida would better inform conservation measures. We present six suggestions for future research.

Studies to quantitatively link Florida coastal waterbird population sizes with prey productivity, abundance, and availability

Our review of the literature reveals that most published accounts of bird diets were the results of observations made at nesting sites rather than at foraging sites. In order to better understand the relationship between bait fisheries and coastal waterbirds, concerted efforts must be undertaken to collect samples at foraging sites.

Model the effects of climate change on forage fish

Climate change is affecting everything from storm frequency, water temperatures, seasonality of currents, and ocean acidification. Prey populations will respond to these perturbations, and effects on predators will follow. Modeling the effects of climate change on prey availability, abundance and diversity would provide important guidance to the conservation community's adaptation strategies for these species.

Identify forage fish species of local importance to Florida coastal waterbirds

Mortality events involving coastal birds frequently bring reports of emaciation from the wildlife rehabilitation community. It is unclear whether this emaciation is a result of diminished prey availability or is a symptom of an underlying pathology. Polling wildlife care facilities, assembling disparate necropsy results, and comparing episodic mortality events with annual trends in forage fish availability could begin to show any correlation between diminished prey availability and these events.

A citizen science program such as The Seabird Ecological Assessment Network, or SeaNet (http://seanetters.wordpress.com/about/), could prove useful in the future with a commitment to apply the data collected. Studies of the sizes, types and amounts of fish adult birds feed to their chicks at key nesting sites in Florida also could begin to characterize forage fish prey species of local importance.

Studies on the effect of bycatch on seabird behavior and populations

Some nesting species, such as Royal and Sandwich Terns, Brown Pelican, and Laughing Gull have been shown to opportunistically exploit prey available from fisheries bycatch (discarded non-target fish) in waters near their nesting islands.[68] This change in behavior could mask or delay the effects of a reduced forage fish base on seabirds by replacing their natural food source. Should commercial fishing and shrimping near these colonies be reduced or eliminated, these colonies should be closely monitored for possible consequences.

Collaborative research on the interaction of pelagic birds and forage fish

Many pelagic birds that forage in federal waters off Florida's coast are poorly understood and are challenging to study because of their wide foraging ranges and low densities, and because research conducted so far out at sea is expensive. At the same time, several of these species migrate long distances, depending upon the predictable timing of currents, weather patterns, and prey abundance and availability. These factors are vulnerable to climate perturbations; accordingly, these difficult-to-study birds may show some of the earliest signs of system disruption.

Partnerships with pelagic birding trips and with deep-sea anglers to sample forage fish and provide observations when they encounter these birds could add to the body of knowledge on this conservation frontier. Both groups seek out these birds--birders to observe them directly, and anglers because they indicate the presence of forage fish, which are often followed by the angler's target species.

Adopt international recommendations for diet sampling methods and reporting

More standardized collection protocols and reporting methods are necessary to allow comparisons across studies of seabird diets. Recommendations from the Working Group on Seabird Ecology of the International Council for the Exploration of the Sea on diet-sampling methods and standardized reporting should be reviewed and adopted in further research in Florida.[62]

Endnotes

1 Philippe M. Cury et al., "Global Seabird Response to Forage Fish Depletion—One-third for the Birds," Science 334, no. 6063 (2011): 1703–06.

2 Anthony DM. Smith et al., "Impacts of Fishing Low–Trophic Level Species on Marine Ecosystems," Science. 333 (2011): 1147-50, plus supplemental online information.

3 E.K. Pikitch et al., *Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs*, Lenfest Ocean Program (2012). Washington, DC. 108.

4 Anthony D.M. Smith et al., "Impacts of Fishing Low–Trophic Level Species on Marine Ecosystems"; E. K. Pikitch et al., *Little Fish, Big Impact*

5 J.C. Ogden et al., In Press. "Identification of a suite of water birds to act as indicators of the marine habitats of southern Florida" for submission to *Ecological Indicators*.

6 Florida Fish and Wildlife Conservation Commission. Fast Facts webpage available at http://myfwc.com/about/overview. Last viewed on November 12, 2013.

7 J.A. Kushlan, "Feeding Behavior of North American Herons," *The Auk* 93 (1976): 86–94; H. Haffner et al., "Flock Feeding and Food Intake in Little Egrets *Egretta grazetta* and Their Effects on Food Provisioning and Reproductive Success," *Ibis* 135 (1993): 223–251.

8 C.P. Onuf, J.M. Teal, and J. Valiela, "Interactions of Nutrients, Plant Growth and Herbivory in a Mangrove Ecosystem," Ecology 58 (1977): 514–526; P.C. Frederick and G.V.N. Powell, "Nutrient Transport by Wading Birds in the Everglades," in *The Everglades: The Ecosystem and Its Restoration*, ed. S.M. Davis and J.C. Ogden (Delray Beach: St. Lucie Press, 1994), 571–584.

9 K.L. Bildstein, *White Ibis: Wetland Wanderer* (Washington, DC: Smithsonian Institution Press, 1993).

10 E.K. Pikitch et al., "The global contribution of forage fish to marine fisheries and ecosystems" Fish and Fisheries. doi: 10.1111/faf.12004 (2012), http://users.soe.ucsc.edu/~msmangel/Pikitch%20et%20al.%20F%20and%20F%202012.pdf.

11 R.W. Butler, "Time of breeding in relation to food availability of female Great Blue Herons," The Auk 110: (1993) 693–70; E.D. Stolen, R.B. Smith, and D.R. Breininger. "Analysis of Wading Bird Use of Impounded Wetland Habitat on the Kennedy Space Center/Merritt Island National Wildlife Refuge: 1987-1998," NASA Technical Memorandum 211173 (2002), http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20030013644_2002102946.pdf.

12 P.M. Cury, "Global Seabird Response to Forage Fish Depletion–One third for the Birds."

13 E.K. Pikitch et al, *Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs*, Lenfest Ocean Program (2012). Washington, DC.

14 M.L. Pinsky et al., "Unexpected patterns of fisheries collapse in the world's oceans," *Proceedings of the National Academy of Sciences*, 108(20), (2011): 8317; M. Barange, et al. "Current trends in the assessment and management of small pelagic fish stocks." In D.M Checkley, C. Roy, J. Alheit, and Y. Oozeki (Eds.), *Climate Change and Small Pelagic Fish.* (Cambridge, UK: Cambridge University Press, 2009), 191–256.; K. Patterson. "Fisheries for small pelagic species: an empirical approach to management targets." "Reviews" in *Fish Biology and Fisheries*, 2(4), (1992): 321–338.

15 "Florida Fish and Wildlife Conservation Commission, Marine Fisheries Information System, 2012 Annual Landings Summary, Edited Landings Data Through Batch 1199 (Closed August 13, 2013)," last modified September 5, 2013, http://myfwc.com/media/2641818/sumstate_12.pdf. See also, Wakulla Commercial Fishermen's Assocation, Inc. and Ronald Fred Crum, Jonas Porter and Keith Ward vs. Florida Fish and Wildlife Conservation Commission, Case No.: 2011-CA-2196; Second Judicial Circuit for Leon County, Florida.

16 Elizabeth A. Forys et al., "Roof-nesting Least Terns Travel to Forage in Brackish/marine Waters" *Southeastern Naturalist* 12 (2013): 238-242; Jonathan L. Atwood and Dennis E. Minsky, "Least Tern Foraging Ecology at Three Major California Breeding Colonies," Western Birds 14 (1983): 57–72.

17 Jonathan L. Atwood and Paul R. Kelly, "Fish Dropped on Breeding Colonies as Indicators of Least Tern Food Habits," *The Wilson Bulletin* 96 (1984): pp. 34–47 ; Raymond G Carreker, "Habitat Suitability Index Models: Least Tern," *U.S. Fish and Wildlife Service Biological Report* 82, no. 10.103 (1985).

18 Atwood and Kelly, "Fish Dropped on Breeding Colonies as Indicators of Least Tern Food Habits."

19 Florida Fish and Wildlife Conservation Commission, *Black Skimmer Biological Status Review Report*.

20 M.R. Yancey and E.A. Forys. "Black skimmers (*Rynchops niger*) forage when light levels are low," *Waterbirds*. 33 (2010): 556-559.

21 R. Michael Erwin, "Foraging and Breeding Adaptations to Different Food Regimes in Three Seabirds: The Common Tern, *Sterna hirundo*, Royal Tern, *Sterna maxima*, and Black Skimmer, *Rynchops niger*," *Ecology* 58 (1977): 389–397; Robert W. Loftin, "Diet of Black Skimmers and Royal Terns in Northeastern Florida," *Florida Field Naturalist* 10 (1982): 19–20.

22 R. Michael Erwin, "Black Skimmer Breeding Ecology and Behavior," *The Auk* 94 (1977): pp. 709–717.

23 Mark Shields, "Brown Pelican (*Pelecanus occidentalis*)," in The Birds of North America Online, ed. A. Poole (Ithaca: Cornell Lab of Ornithology, 2002).

24 Palmer, R.S. "Handbook of North American Birds," in *Handbook of North American Birds* (New Haven: Yale University Press, 1962), 280.

25 Michael J. Fogarty, Stephen A. Nesbitt, and Carter R. Gilbert, "Diet of Nestling Brown Pelicans in Florida," *Florida Field Naturalist* 9 (1981): 38–40.

26 James A. Kushlan and Paula C. Frohring, "Decreases in the Brown Pelican Population in Southern Florida," *Colonial Waterbirds* 8 (1985): 83–95.

27 M. Gochfeld, "The Roseate Tern: World Distribution and Status of a Threatened Species," *Biological Conservation* 25 (1983): 103–125.

28 David A. Shealer, "Foraging Habitat Use and Profitability in Tropical Roseate Terns and Sandwich Terns," *The Auk* 113 (1996): 209–217; David A Shealer, "Differences in Diet and Chick Provisioning Between Adult Roseate and Sandwich Terns in Puerto Rico," *The Condor* 100 (1998): 131–140.

29 Michael Gochfeld, Joanna Burger, and Ian C. Nisbet, "Roseate Tern (Sterna dougallii)," in *The Birds of North America Online*, ed. A. Poole (Ithaca: Cornell Lab of Ornithology, 1998).

30 Gochfeld, "The Roseate Tern: World Distribution and Status of a Threatened Species."

31 Peter E. Lowther and Richard T. Paul, "Reddish Egret (*Egretta Rufescens*)," in *The Birds of North America Online*, ed. A. Poole (Ithaca: Cornell Lab of Ornithology, 2002).

32 Lowther and Paul, "Reddish Egret (*Egretta rufescens*)."

33 Florida Fish and Wildlife Conservation Commission, *Roseate Spoonbill Biological Status Review Report.*

34 Clarence Cottam and Phoebe Knappen, "Food of Some Uncommon North American Birds," *The Auk* 56 (1939): 138–169.

35 George V.N. Powell and Robin D. Bjork, "Relationships Between Hydrologic Conditions and Quality and Quantity of Foraging Habitat for Roseate Spoonbills and Other Wading Birds in the C-111 Basin," *Annual Report to the South Florida Research Center, Everglades National Park, National Park Service* (1989).

36 Meyer L. Ueoka and James R. Koplin, "Foraging Behavior of Ospreys in Northwestern California," *Journal of Raptor Research* 7 (1973): 32–38.

37 B.P. Greene, A.E. Greene, and B. Freedman, "Foraging Behavior and Prey Selection by Ospreys in Coastal Habitats in Nova Scotia, Canada," in *Biology and Management of Bald Eagles and Ospreys*, ed. D.M. Bird (Montreal: McGill University: Macdonald Raptor Research Center, 1983); R.S. Palmer, (Ed.), *Handbook of North American Birds*, Vol. 4 (New Haven: Yale University Press, 1988).

38 John C. Ogden, "Effects of Bald Eagle Territoriality on Nesting Ospreys," *The Wilson Bulletin* 87 (1975): 496–505; J.C. Ogden, "Preliminary Report on a Study of Florida Bay Ospreys," ed. J.C. Ogden, *The Wilson Bulletin* 87 (1975): 496–505; J.C. Ogden, "Osprey," in Rare and Endangered Biota of Florida, Volume 5: Birds, ed. J.A. Rodgers, H.W. Kale, and H.T. Smith (Gainesville: University of Florida Press, 1996), 170–177; A.F. Poole, "Brood Reduction in Temperate and Sub-tropical Ospreys," *Oecologia* 53 (1982): 111–119.

39 Ueoka and Koplin, "Foraging Behavior of Ospreys in Northwestern California."

40 Poole, "Brood Reduction in Temperate and Sub-tropical Ospreys."

41 Greene, Greene, and Freedman, "Foraging Behavior and Prey Selection by Ospreys in Coastal Habitats in Nova Scotia, Canada."

42 Robert A. Ronconi, Peter G. Ryan, and Yan Ropert-Coudert, "Diving of Great Shearwaters (*Puffinus gravis*) in Cold and Warm Water Regions of the South Atlantic Ocean.," PloS One 5 (January 2010).

43 Maria Virginia Petry et al., "Shearwater Diet During Migration Along the Coast of Rio Grande Do Sul, Brazil," *Marine Biology* 154 (2008): 613–621; Ronconi, Ryan, and Ropert-Coudert, "Diving of Great Shearwaters (*Puffinus gravis*) in Cold and Warm Water Regions of the South Atlantic Ocean."

44 *Porichthys porosissimus* (Atlantic midshipman), *Ctenosciaena gracilicirrhus* (barbel drum), *Paralonchurus brasiliensis* (banded croaker), *Cynoscion guatucupa* (striped weakfish), and *Trichiurus lepturus* (largehead hairtail)

45 David S. Lee, "Mass Die-offs of Greater Shearwaters in the Western North Atlantic: Effects of Weather Patterns on Mortality of a Trans-equatorial Migrant," *The Chat,* 73 (2009):37-47.

46 Donald J. Forrester et al., "Winter Mortality of Common Loons in Florida Coastal Waters," *Journal of Wildlife Diseases* 33 (1997): 833–847.

47 David C. Evers et al., "Common Loon (*Gavia immer*)," in The Birds of North America Online, ed. A. Poole (Ithaca: Cornell Lab of Ornithology, 2010).

48 P. J. Ewins et al., "The Diet of Herring Gulls (*Larus argentatus*) During Winter and Early Spring on the Lower Great Lakes," *Hydrobiologia* 279/280 (April 1994): 39–55.

49 R.J. Pierotti and T.P. Good, "Herring Gull (*Larus argentatus*)," in *The Birds of North America Online*, ed. A. Poole (Ithaca: Cornell Lab of Ornithology, 1994).

50 The State of World Fisheries and Aquaculture, 2012. Food and Agriculture Organization of the United Nations. 230 pp http://www.fao.org/docrep/016/i2727e/i2727e00.htm

51 Alder, J., eta/. (2008). Forage fish: from ecosystems to markets. *Annual Review of Environment and Resources*, 33, 1 53-166. In, Pikitch, E., Boersma, P.D., Boyd, l.L., Conover, D.O., Cury, P., Essington, T., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plaganyi, E.,Sainsbury, K., and Steneclc, R.S. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp.

52 NOAA 10-Year Plan for Marine Aquaculture. October 2007. U.S. Department of Commerce. 23pp. http://www.nmfs.noaa.gov/aquaculture/docs/policy/final_noaa_10_yr_plan.pdf

53 Southeast Fishery Bulletin, FB09-035. June 4, 2009. http://sero.nmfs.noaa.gov/fishery_bulletins/bulletin_archives/2009/documents/pdfs/fb09-035_noa_aquaculture.pdf and http://www.gulfcouncil.org/Beta/GMFMCWeb/Aquaculture/Aquaculture%20FMP%20PEIS%20Final%202-24-09.pdf

54 The Today Show, NBC, broadcast on October 12, 2012. http://www.today.com/video/today/49387236#49387236

55 *New York Times* article published July 2231, 2013 by John T Edge. http://www.nytimes.com/2013/07/24/dining/bottarga-an-export-that-stays-at-home.html?_r=0

56 Ibid

57 Wakulla Commercial Fishermen's Assocation, Inc. and Ronald Fred Crum, Jonas Porter and Keith Ward vs. Florida Fish and Wildlife Conservation Commission, Case No.: 2011-CA-2196; Second Judicial Circuit for Leon County, Florida.

58 "Staff Summary, Meeting of November 7, 2012." State of California Fish and Game Commission. http://www.fgc.ca.gov/meetings/2012/110712summary.pdf.

59 Atlantic States Marine Fisheries Commission, "ASMFC Approves Atlantic Menhaden Amendment 2," Atlantic States Marine Fisheries Commission Press Release (Dec. 14, 2012).

60 John P. Croxall et al., "Seabird conservation status, threats and priority actions: a global assessment." *Bird Conservation International* 22 (2012):pp. 1-34.

61 Cury et al., "Global Seabird Response to Forage Fish Depletion—One-third for the Birds."

62 Erwin, "Foraging and Breeding Adaptations to Different Food Regimes in Three Seabirds"; Erwin, "Black Skimmer Breeding Ecology and Behavior."

63 M. Vincx, E. Kuijken, and F. Volckaert, SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY II: *Higher Trophic Levels in the Southern North Sea, Scientific Support Plan for a Sustainable Development Policy*, Part 2: Global Change, Ecosystems and Biodiversity (Brussels, 2007), http://www.belspo.be/belspo/organisation/publ/pub_ostc/EV/rappEV25_en.pdf,.

64 "Biological status reviews of imperiled species," Florida Fish and Wildlife Conservation Commission, 2011. See Black Skimmer, Least Tern, Reddish Egret, Snowy Egret: http://myfwc.com/wildlifehabitats/imperiled/biological-status/.

65 J.A. Ramos, E. Sola, and L R. Monteiro, "Prey delivered to Roseate Tern chicks in the Azores," *Journal of Field Ornithology* 69 (1998): 419-429.

66 J.J. Lorenz. "The response of fishes to physicochemical changes in the mangroves of northeast Florida Bay," *Estuaries* 22 (1999): 500-517.

67 J.J. Lorenz, "The relationship between water level, prey availability and reproductive success in Roseate Spoonbills foraging in a seasonally-flooded wetland while nesting in Florida Bay," *Wetlands* DOI: 10.1007/s13157-012-0364-y (2013).

68 Patrick G. R. Jodice, , Lisa C. Wickliffe, and Elena B. Sachs, "Seabird Use of Discards from a Nearshore Shrimp Fishery in the South Atlantic Bight, USA." *Marine Biology*, 158 (2011): 2289–2298.

69 Robert T. Barrett et. al. "Diet Studies of Seabirds: a Review and Recommendations." *International Council for the Exploration of the Sea* (2007), 1675-1691, http://icesjms.oxfordjournals.org/content/64/9/1675.full.pdf+html.

Appendix B. Diet summary of Florida Coastal Waterbirds

This table lists Florida coastal bird species that forage on marine fish and summarizes their diet composition reported in the reviewed literature

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Seabirds Breeding in Peninsular Florida					
Least Tern	Threadfin shad, halfbeak, striped mullet, bay anchovy, menhaden, sailfin molly, pinfish, Spanish sardine, spot	Sand lance, herring, hake, anchovies, menhaden, silversides, smelt, surfperch, mosquitofish, rough silverside, flat croaker, mummichogs	Crustaceans, marine worms, and insects	Shallow plunge-diving; surface dipping; hawks insects in flight; plucks invertebrate prey on shore	(Forys et al. 2013; Atwood and Minsky 1983; Atwood and Kelly 1984; Carreker 1985)
Black Skimmer	Striped mullet, mummichog, Atlantic menhaden, flounder, ladyfish, sharksucker, needlefish, snapper, killifish	Silversides, killifish, bay anchovy, mullet, spot, bluefish	Shrimp	"Skimming"—it flies while trailing mandible in water until prey is captured	(Leavitt 1957; Erwin 1977; Loftin 1982; Gochfeld and Burger 1994)
Royal Tern	Atlantic menhaden, Atlantic croaker, banded drum, Atlantic thread herring, spotted sea trout, spot, Spanish sardine, striped anchovy, bay anchovy, silver perch, southern kingfish, Atlantic bumper, jack, shad, cusk eel	Silversides, anchovies, menhaden, sardines, herring, shad drums and croakers, porgies, mullet, jacks, mackerels, tunas, bonitos, anchovies	Crustaceans (mainly shrimp), squid	Shallow plunge-diving	(Loftin 1977; Buckley and Buckley 2002)
Sandwich Tern		Mullet, sand lance, garfish, sardines, dwarf herring	Squid, shrimp, insects	Plunge-diving	(Shealer 1999)
Caspian Tern		Jacksmelt, shiner perch, staghorn sculpin, northern anchovy, topsmelt, shiner perch, chum salmon, Pacific sardine, juvenile salmonids (coho, chinook, steelhead, sockeye)	Crayfish, insects (occasionally)	Shallow plunge-diving	(Cuthbert and Wires 1999)
Gull-billed Tern		American eel, killifish, pipefish, toadfish, tilapia	Insects, arachnids, crabs, shrimp, lizards (anoles), frogs, small chicks of other birds	Surface dipping; plucks crustaceans and other prey onshore or in shallow water; hawks insects.	(Rohwer and Woolfenden 1968; Erwin et al. 1998; Molina, Parnell, and Erwin 2009)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Laughing Gull		No fish species given, although most studies mention fish in the diet	Aquatic and terrestrial invertebrates, including earthworms, insects, snails, crabs, crab eggs, crab larvae, echinoderms, shrimp, squid, mollusks, small crustaceans, small lobsters, garbage, offal, berries, horseshoe-crab eggs, fiddler crabs	Plucks food from shallow water or on shore; surface dipping; hawks insects; takes eggs and chicks of other birds; shallow plunge-diving; kleptoparasitic (steals food)	(Burger 1996)
Double-crested Cormorant	Gulf toadfish, bluestriped grunt, white grunt, bucktooth parrotfish, pinfish, barbfish, sand perch, gray snapper, freshwater fish	At least 250 species of fish from more than 60 families reported as prey	Some aquatic animals (insects, crustaceans, amphibians)	Dives from surface and pursues fish underwater	(Cummings 1987; Hatch and Weseloh 1999)
Brown Pellican	Menhaden, silversides, dolphin, mullet, Atlantic threadfin, sea trout, spot, pinfish, sardines, bay anchovy	Menhaden, mullet, anchovies, herrings, sailfin mollies, dwarf herring, sardines	Prawns	Plunge-diving to depths of 1-2 m	(Shorger 1962; Fogarty, Nesbitt, and Gilbert 1981; Kushlan and Frohring 1985; Shields 2002)
Seabirds Breeding Only in Florida Keys					
Roseate Tern		Dwarf herring, anchovies, sardines, sand eels, bay anchovy, Atlantic herring, blueback herring, Atlantic menhaden, Atlantic mackerel, Atlantic silverside, bluefish, white hake	Insects, squid, small crustaceans	Shallow plunge-diving, surface dipping	(Shealer 1996; Gochfeld, Burger, and Nisbet 1998)
Magnificent Frigatebird		Flying fish	Squid	Surface dipping and opportunistic klepto-parasitism	(Calixto-Albarran and Jose-Luis 2000; Diamond and Schreiber 2002)
Sooty Tern	Clupeids (herring, shad, sardine, menhaden), halfbeaks, flyingfishes, squirrelfish and soldierfish sea basses, jacks, dolphinfish, goatfish, jawfish, gobies, mackerels, tunas, bonitos, driftfish	jacks, flyingfishes, squirrelfish and soldierfish, goatfish, jawfish, gobies and sea basses	Squid	Shallow plunge-diving; surface dipping	(Harrison, Hida, and Seki 1983; Hensley and Hensley 1995)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Brown Noddy	Clupeids (herring, shad, sardine, menhaden), halfbeaks, flyingfishes, squirrelfish and soldierfish, goatfish, jawfish, gobies, mackerels, tunas, bonitos, driftfish	In Puerto Rico, Spanish sardine and small larval fishes (including anchovies). In other places: goatfish, flying fish, and snake mackerels, bluefish	Squid	Takes prey from sea surface or just below by dipping or surface seizing	(Chardine and Morris 1996; Hensley and Hensley 1995)
Bridled Tern		Triggerfish, puffers, jacks, butterflyfish, trunkfish, bigeye, pipefish, bluefish	Squid, crustaceans, insects	Shallow plunge-diving; surface dipping; hawks insects	(Haney, Lee, and Morris 1999)
Masked Booby		Flying fishes, jacks	Squid	Plunge-diving and swimming underwater	(Harrison, Hida, and Seki 1983; Grace and Anderson 2009)
Florida-breeding Wading Birds (Florida Breeders)					
Reddish Egret	Sheepshead minnow, sailfin molly, goldspotted killifish, killifish	Sheepshead minnow, Longnose killifish, pinfish, striped mullet, tidewater silverside, ladyfish	The often cited listing of frogs and tadpoles (based on Cahn 1923) is either exceptional or incorrect	Actively chases fish by running, flicking or opening its wings and grabbing disturbed prey. Forms canopy with its wings over its head and grabs fish attracted by the shadow. Wades and scrapes foot on bottom to stir up fish	(McMurry 1971; Simersky 1971; Lowther and Paul 2002)
Great Egret		Longtoms, catfish, surfperch, sole, mummichog, Atlantic menhaden, spotted sunfish, sailfin mollies	invertebrates, amphibians, reptiles	Stabs or captures prey while standing or walking slowly in shallow water	(Schlorff 1978; Mccrimmon, Ogden, and Bancroft 2011)
Snowy Egret	Pipefish, needlefish, and mosquitofish	Sheepshead minnow, mummichogs, Atlantic silverside, killifish, bay anchovy	Earthworms, annelid worms, aquatic and terrestrial insects, crabs, shrimp, prawns, crayfish, other crustaceans, snails, frogs/toads, and snakes/lizards (Kushlan 1978a; Kushlan 1978b).	Very broad behavioral repertoire (standing, bill-vibrating head-swaying, wing-flicking, etc.)	(Kushlan 1978b; Parsons and Master 2000)
Great Blue Heron		Goldspotted killifish, mullet, redfin needlefish, American eel, white perch, northern pipefish, flounders, sculpin	Small rodents, chicks of colonial seabirds, and snakes	Stabs or captures prey while standing or walking slowly in water or on shore	(Bent 1927a; Willard 1977; Ramo and Busto 1993)
Little Blue Heron	Mosquitofish, sailfin molly, and swamp darter, among other primarily freshwater species		Substrate-crawling crustaceans (primarily freshwater crayfish, some soft-shelled blue crabs, prawns	Stabs or captures prey while standing or walking slowly in shallow water	(Kushlan 1978a; Rodgers 1982)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Green Heron		Topminnows, minnows, sunfish, catfish, pickerel, carp, perch, gobies, shad, silversides, eels, tropical fish	Crayfish	Stabs or captures prey from perch over water or while standing in shallow water	(Betts and Betts 1977; Niethammer and Kaiser 1983; Davis and Kushlan 1994; Avery et al. 1999; Englund and Krupa 2000)
Black-crowned Night Heron		Whiting, herring, cunners, small flounder		Stabs or captures prey while walking or standing in shallow water	(Gross 1923; Bent 1927b)
Roseate Spoonbill	Sheepshead minnow, sailfin molly, marsh killifish, and sunfish	Silversides and sheepshead minnow	Crustaceans, insects	Searches for prey by scything partially open bill from side to side through water or mud while walking; when prey contacts spoon, bill clamps shut	(Cottam and Knappen 1939; Allen 1942; Powell and Bjork, 1989; Dumas 2000)
Fish-eating Birds of Prey (Florida Breeders)					
Osprey	Gafftopsail and hardhead catfish, jacks, spotted sea trout, pinfish, filefish, sheepshead porgy	Striped and white mullet, surf perch, winter flounder, alewife, smelt, winter flounder, pollock		Plunge-diving	(Ueoka and Koplin 1973; Ogden 1975a; Ogden 1975b; Ogden 1996; Poole 1982; Greene, Greene, and Freedman 1983; Palmer 1988)
Bald Eagle	Mullet, sea catfish, jacks	Rockfish, surfperch, cabezon, midshipmen, sheepshead, chum salmon carcasses	Mammals, reptiles, seabirds, waterfowl	Plunge-diving, scavenging, kleptoparasitism	(Bent 1937; Ogden 1975; Haywood and Ohmart 1986; Mabie, Merendino, and Reid 1995; Jackman et al. 1999; Collins et al. 2005; Harvey, Good, and Pearson 2012)
Pelagic Foraging Species					
Northern Gannet		Mackerel, herring, capelin, cod, coalfish, whiting, haddock, sprat, pilchard, garfish, sand lance, post-smolt Atlantic salmon, Atlantic saury, sand eel, smelt, flounder, pollock, menhaden	Squid, shrimp	Plunge-diving and swimming underwater	(Mowbray 2002)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
White-tailed Tropicbird		Mackerel, scad, flying fish, triggerfish, needlefish, jacks, clupeids (herring, shad, sardines, menhaden), halfbeaks, dolphinfish, flying gurnards, flyingfish, sea chub, cusk-eels, bigeyes, butterfish, cutlassfish, swordfish	No information available	Shallow plunge-diving; surface dipping	(Lee and Walsh-Mcgehee 1998; Catry et al. 2009)
Black-capped Petrel		No species information available	Squid and sargassum	Shallow plunge-diving; surface dipping	(Haney 1987; Simons et al. 2006)
Band-rumped Storm-petrel		No species information available	No information available	Shallow plunge-diving; surface dipping	(Harrison, Hida, and Seki 1983)
Audubon's Shearwater		Primarily goatfish; also jacks, anchovies and fish larvae	No information available	Pplunge-diving and swimming underwater	(Catry et al. 2009)
Greater Shearwater		Drums, croakers, toadfish, cutlassfish	Cephalopods* (primarily squid)	Plunge-diving and swimming underwater	(Petry et al. 2008; Ronconi, Ryan, and Ropert-Coudert 2010)
White Pelicans and Duck-like Birds					
American White Pelican		Small schooling fish (less than one-half bill length), channel catfish, grass carp, farm-raised catfish	Salamanders, tadpoles, crayfish	Plunge-diving; group foraging while swimming in flocks is common in non-breeding season	(Knopf and Evans 2004; King 2005)
Red-throated Loon		Capelin, herring, sprat, sand eel, arctic char, sculpin, cod, sand lance	Marine worms, copepods, and crustaceans	Diving	(Barr, Eberl, and Mcintyre 2000)
Common Loon		Menhaden, croaker, spot, silversides	Crabs, flounder, lobster	Diving	(Evers et al. 2010)
Hooded Merganser		Marine species unknown	Crustaceans (crayfish, mud crabs), molluscs, aquatic insects, frogs	Diving	(Palmer 1988; Dugger, Dugger, and Fredrickson 2009)
Red-breasted Merganser		Sculpin (grubby), sand lance, killifish, silversides, blueback herring in Texas, a wide variety of small fish—notably Gulf toadfish	Shrimp, invertebrates	Diving	(Craik et al. 2011)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Wintering Gulls and Terns					
Ring-billed Gull		Alewives, smelt, sticklebacks, yellow perch, mummichogs	Earthworms, insects, grains, small mammals, garbage	Plucks food from shallow water or on shore; hawks insects; shallow plunge-diving; surface dipping; forages for grain in fields	(Pollet et al. 2012)
Herring Gull		Clupeids (herrings, shad, menhaden, sardines) salmon, smelts, pikes, suckers, minnows, freshwater catfishes, sea basses, sunfish, perch, silversides	Sea urchins, jonah and rock crabs, green crabs, crayfish, mussels, Leach's Storm-Petrel, squid, tern chicks, clams, refuse	Plucks prey in shallow water or on shore; surface dipping; shallow plunge-diving; forages in pelagic settings where upwelling occurs and prey concentrates.	(Pierotti and Good 1994; Ewins et al. 1994)
Bonaparte's Gull		Young herring, harbor pollock, shad, rockfish, salmonids	Grasshoppers, beetles, locusts, ants, other insects, marine worms, crustacea, snails, euphausids, amphipods, snails, mussels, mysids, crabs	Shallow plunge-diving, surface dipping; plucks prey on shore or from water surface while swimming; shallow dives	(Braune 1987; Burger and Gochfeld 2002)
Great Black-backed Gull		Atlantic herring, lumpfish, Atlantic mackerel, sculpin, Atlantic sea raven , American eel, rock gunnel, Atlantic cod, pollock, Atlantic salmon, spiny dogfish, capelin, Atlantic tomcod	Northern krill, waste (fisheries and domestic), Gull chicks, Common Eider ducklings, Leach's Storm-Petrel, Atlantic Puffin, Herring Gull chicks, other birds, squid, insects, sea urchin, other marine invertebrates	Plucks prey on shore or in shallow water; surface dipping; shallow plunge-diving	(Good 1998; Gilliland, Ankney, and Hicklin 2004)
Lesser Black-backed Gull		Gadids (whiting, cod, bib, haddock, saithe), clupeids (herring), garfish, gurnards, mackerel, scad, dragonets, hooknose, dab	Mollusks, crustaceans, insects, echinoderms, bird eggs, mammals, cereal, fruit, garbage	Surface dipping; shallow plunge-diving	(Garthe et al. 1999)
Forster's Tern		Shiner perch, northern anchovy, and arrow goby		Shallow plunge-diving; surface dipping	(Baltz, Morejohn, and Antrim 1979; Mcnicholl, Lowther, and Hall 2001)

Bird Species	Fish Prey in FL	Fish Prey Elsewhere	Non-fish Food Items	Foraging Method	Reference(s)
Common Tern		American sand lance, capelin, threespined stickleback, Atlantic herring, pollock, striped mummichog, shad, hake, fourbeard rockling, butterfish, anchovies, Atlantic silverside, cunner, northern pipefish, bluefish, butterfish, Atlantic mackerel, killifish	Shrimp, prawns, crabs, Squid, marine invertebrates, insects	Shallow plunge-diving; surface dipping	(Nisbet 2002)
Black Tern		Anchovies, silversides	Plankton, marine water striders, other insects	Shallow plunge-diving; surface dipping	(Heath, Dunn, and Agro 2009)

References for Appendix B

Allen, Robert Porter. 1942. "The Roseate Spoonbill." *Research Report No. 2 of the National Audubon Society*.

Atwood, Jonathan L, and Paul R Kelly. 1984. "Fish Dropped on Breeding Colonies as Indicators of Least Tern Food Habits." *The Wilson Bulletin* 96 (I): 34–47.

Atwood, Jonathan L., and Dennis E. Minsky. 1983. "Least Tern Foraging Ecology at Three Major California Breeding Colonies." *Western Birds* 14 (2): 57–72.

Avery, Michael L., David S. Eiselman, Mark K. Young, John S. Humphrey, and David G. Decker. 1999. "Wading Bird Predation at Tropical Aquaculture Facilities in Central Florida." *North American Journal of Aquaculture* 61: 64–69.

Baltz, Donald M., Victor G. Morejohn, and Brooke S. Antrim. 1979. "Size Selective Predation and Food Habits of Two California Terns." *Western Birds* 10: 17–24.

Barr, Jack F., Christine Eberl, and Judith W. Mcintyre. 2000. "Red-throated Loon (*Gavia stellata*)." In *The Birds of North America Online,* ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Bent, Arthur Cleveland. 1927a. "Great Blue Heron." *Smithsonian Institution United States National Museum Bulletin* 135: 101–114.

———. 1927b. "Black-crowned Night Heron." *Smithsonian Institution United States National Museum Bulletin* 135: 197–213.

———. 1937. "Bald Eagle." *Smithsonian Institution United States National Museum Bulletin* 167 (Part 1): 321–333.

Betts, Burr J., and Donna L. Betts. 1977. "The Relation of Hunting Site Changes to Hunting Success in Green Herons and Green Kingfishers." *The Condor* 79 (2): 269–271.

Braune, Birgit M. 1987. "Seasonal Aspects of the Diet of Bonaparte's Gulls (*Larus philadelphia*) in the Quoddy Region, New Brunswick, Canada." *The Auk* 104 (2): 167–172.

Buckley, P.A., and Francine G. Buckley. 2002. "Royal Tern (*Thalasseus maximus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Burger, Joanna. 1996. "Laughing Gull (*Leucophaeus atricilla*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Burger, Joanna, and Michael Gochfeld. 2002. "Bonaparte's Gull (*Chroicocephalus philadelphia*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Calixto-Albarran, Itzia, and Osorno Jose-Luis. 2000. "The Diet of the Magnificent Frigatebird During Chick Rearing." *The Condor* 102: 569–576.

Carreker, Raymond G. 1985. "Habitat Suitability Index Models: Least Tern." *U.S. Fish and Wildlife Service Biological Report* 82 (10.103).

Catry, T., Ja Ramos, S. Jaquemet, L. Faulquier, M. Berlincourt, A. Hauselmann, P. Pinet, and M. Le Corre. 2009. "Comparative Foraging Ecology of a Tropical Seabird Community of the Seychelles, Western Indian Ocean." *Marine Ecology Progress Series* 374 (January 13): 259–272.

Chardine, John W., and Ralph D. Morris. 1996. "Brown Noddy (*Anous stolidus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Collins, Paul W., Daniel A. Guthrie, Torben C. Rick, and Jon M. Erlandson. 2005. "Analysis of Prey Remains Excavated from an Historic Bald Eagle Nest Site on San Miguel Island, California." In *Proceedings of the Sixth California Islands Symposium, Ventura, California, December 1-3, 2003*, ed. D.K. Garcelon and C.A. Schwemm, 103–120. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, CA.

Cottam, Clarence, and Phoebe Knappen. 1939. "Food of Some Uncommon North American Birds." *The Auk* 56 (2): 138–169.

Craik, S.R., J.P.L. Savard, M.J. Richardson, and R.D. Titman. 2011. "Foraging Ecology of Flightless Male Red-breasted Mergansers in the Gulf of St. Lawrence, Canada." *Waterbirds* 34 (3): 280–288.

Cummings, M.V. 1987. "The Feeding Energetics of the Double-crested Cormorant in Biscayne Bay, Florida." University of Miami.

Cuthbert, Francesca J., and Linda R. Wires. 1999. "Caspian Tern (*Hydroprogne caspia*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Davis, W.E., Jr., and James A Kushlan. 1994. "Green Heron (*Butorides virescens*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Diamond, Anthony W., and Elizabeth A. Schreiber. 2002. "Magnificent Frigatebird (*Fregata magnificens*)." In *The Birds of North America Online,* ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Dugger, B.D., K.M. Dugger, and L.H. Fredrickson. 2009. "Hooded Merganser (*Lophodytes cucullatus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Dumas, Jeannette V. 2000. "Roseate Spoonbill (*Platalea ajaja*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Englund, Goran, and James J. Krupa. 2000. "Habitat Use by Crayfish in Stream Pools: Influence of Predators, Depth and Body Size." *Freshwater Biology* 43 (January): 75–83.

Erwin, R. Michael, T. Brian Eyler, Jeff S. Hatfield, and Sabrina McGary. 1998. "Diets of Nestling Gull-Billed Terns in Coastal Virginia." *Colonial Waterbirds* 21 (3): 323–327.

Erwin, R. Michael. 1977. "Foraging and Breeding Adaptations to Different Food Regimes in Three Seabirds: The Common Tern, *Sterna hirundo*, Royal Tern, *Sterna maxima*, and Black Skimmer, *Rynchops niger*." *Ecology* 58 (2): 389–397.

Evers, David C., James D. Paruk, Judith W. Mcintyre, and Jack F. Barr. 2010. "Common Loon (*Gavia immer*)." In *The Birds of North America Online,* ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Ewins, P. J., D.V. Weseloh, J.H. Groom, R.Z. Dobos, and P. Mineau. 1994. "The Diet of Herring Gulls (*Larus argentatus*) During Winter and Early Spring on the Lower Great Lakes." *Hydrobiologia* 279/280 (1) (April): 39–55.

Fogarty, Michael J., Stephen A. Nesbitt, and Carter R. Gilbert. 1981. "Diet of Nestling Brown Pelicans in Florida." *Florida Field Naturalist* 9 (3): 38–40.

Forys, Elizabeth.A., Arya Poppema-Bannon, Kristina Krajcik, and William A. Szelistowski. 2013. "Roof-nesting Least Terns Travel to Forage in Brackish/marine Waters." *Southeastern Naturalist* 12 (1): 238–242.

Garthe, Stefan, Tina Freyer, Ommo Huppop, and Dominique Wolke. 1999. "Breeding Lesser Black-Backed Gulls Larus Graellsii and Herring Gulls Larus Argentatus: Coexistence or Competition?" *Ardea* 87 (2): 227–236.

Gilliland, S.G., C.D. Ankney, and P.W. Hicklin. 2004. "Foraging Ecology of Great Black-backed Gulls During Brood-rearing in the Bay of Fundy, New Brunswick." *Canadian Journal of Zoology* 82: 1416–1426.

Gochfeld, Michael, and Joanna Burger. 1994. "Black Skimmer (*Rynchops niger*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Gochfeld, Michael, Joanna Burger, and Ian C. Nisbet. 1998. "Roseate Tern (*Sterna dougallii*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Good, Thomas P. 1998. "Great Black-backed Gull (*Larus marinus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Grace, Jacquelyn, and David J. Anderson. 2009. "Masked Booby (*Sula dactylatra*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Greene, B.P., A.E. Greene, and B. Freedman. 1983. "Foraging Behavior and Prey Selection by Ospreys in Coastal Habitats in Nova Scotia, Canada." In *Biology and Management of Bald Eagles and Ospreys*, ed. D.M. Bird. Montreal: McGill University: Macdonald Raptor Research Center.

Gross, Alfred O. 1923. "The Black-crowned Night Heron (*Nycticorax nycticorax naevius*) of Sandy Neck." *The Auk* 40 (1): 1–30.

Haney, J. Christopher. 1987. "Aspects of the Pelagic Ecology and Behavior of the Black-capped Petrel." *The Wilson Bulletin* 99 (2): 153–168.

Haney, J. Christopher, David S. Lee, and Ralph D. Morris. 1999. "Bridled Tern (*Onychoprion anaethetus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Harrison, C.S., T.S. Hida, and M.P. Seki. 1983. "Hawaiian Seabird Feeding Ecology." *Wildlife Monographs* (85): 3–71.

Harvey, C.J., T.P. Good, and S.F. Pearson. 2012. "Top-down Influence of Resident and Overwintering Bald Eagles in a Model Marine Ecosystem." *Canadian Journal of Zoology* 90 (7): 903–914.

Hatch, Jeremy J., and D.V. Weseloh. 1999. "Double-crested Cormorant (*Phalacrocorax auritis*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology

Haywood, D.D., and R.D. Ohmart. 1986. "Utilization of Benthic-feeding Fish by Inland Breeding Bald Eagles." *The Condor* 88 (1): 35–42.

Heath, Shane R., Erica H. Dunn, and David J. Agro. 2009. "Black Tern (*Chlidonias niger*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Hensley, Valentine I., and Dannie A. Hensley. 1995. "Fishes Eaten by Sooty Terns and Brown Noddies in the Dry Tortugas, Florida." *Bulletin of Marine Science* 56 (3): 813–821.

Jackman, R.E., W.G. Hunt, J.M. Jenkins, and P.J. Detrick. 1999. "Prey of Nesting Bald Eagles in Northern California." *Journal of Raptor Research* 33 (2): 87–96.

Jodice, Patrick G.R., Lisa C. Wickliffe, and Elena B. Sachs. 2011. "Seabird Use of Discards from a Nearshore Shrimp Fishery in the South Atlantic Bight, USA." *Marine Biology* 158 (June 15): 2289–2298.

King, D. Tommy. 2005. "Interactions Between the American White Pelican and Aquaculture in the Southeastern United States : an Overview." *Waterbirds: The International Journal of Waterbird Biology* 28 (Special Publication 1: The Biology and Conservation of the American White Pelican): 83–86.

Knopf, Fritz L., and Roger M. Evans. 2004. "American White Pelican (*Pelecanus erythrorhynchos*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Kushlan, James A. 1978a. "Commensalism in the Little Blue Heron." *The Auk* 95 (4): 677–681.

Kushlan, James A. 1978b. "Feeding Ecology of Wading Birds." In *Wading Birds*, ed. IV Sprunt, A, J.C. Ogden, and S. Winckler, 249–297. New York: National Audubon Society Research Report No. 7.

Kushlan, James A., and Paula C. Frohring. 1985. "Decreases in the Brown Pelican Population in Southern Florida." *Colonial Waterbirds* 8 (2): 83–95.

Leavitt, B.B. 1957. "Food of the Black Skimmer (*Rynchops nigra*)." *The Auk* 74 (3) (February): 394.

Lee, David S., and Martha Walsh-Mcgehee. 1998. "White-tailed Tropicbird (*Phaethon lepturus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Loftin, Robert W. 1977. "A Tern Prey Sample." *Florida Field Naturalist* 5: 47–48.

———. 1982. "Diet of Black Skimmers and Royal Terns in Northeastern Florida." *Florida Field Naturalist* 10 (1): 19–20.

Lowther, Peter E., and Richard T. Paul. 2002. "Reddish Egret (*Egretta rufescens*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Mabie, David W., M. Todd Merendino, and David H. Reid. 1995. "Prey of Nesting Bald Eagles in Texas." *Journal of Raptor Research* 29 (1): 10–14.

Mccrimmon, Donald A. Jr, John C. Ogden, and G. Thomas Bancroft. 2011. "Great Egret (*Ardea alba*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

McMurry, S.L. 1971. "Nesting and Development of the Reddish Egret (*Dichromanassa rufescens gmelin*) on a Spoil Bank Chain in the Laguna Madre." M.S. Thesis. Texas A&M University.

Mcnicholl, Martin K., Peter E. Lowther, and John A. Hall. 2001. "Forster's Tern (*Sterna forsteri*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Molina, K.C., J.F. Parnell, and R.M. Erwin. 2009. "Gull-billed Tern (*Gelochelidon nilotica*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Mowbray, Thomas B. 2002. "Northern Gannet (*Morus bassanus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Niethammer, K.R., and M.S. Kaiser. 1983. "Late Summer Food Habits of Three Heron Species in Northeastern Louisiana." *Colonial Waterbirds* 6: 148–153.

Nisbet, Ian C. 2002. "Common Tern (*Sterna hirundo*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Ogden, John C. 1975a. "Preliminary Report on a Study of Florida Bay Ospreys." Ed. J.C. Ogden. *The Wilson Bulletin* 87 (4): 496–505.

———. 1975b. "Effects of Bald Eagle Territoriality on Nesting Ospreys." *The Wilson Bulletin* 87 (4): 496–505.

———. 1996. "Osprey." In *Rare and Endangered Biota of Florida, Volume 5: Birds*, ed. J.A. Rodgers, H.W. Kale, and H.T. Smith, 170–177. Gainesville: University of Florida Press.

Palmer, R.S. (Ed.). 1988. *Handbook of North American Birds*. Vol. 4. New Haven: Yale University Press.

Parsons, Katharine C., and Terry L. Master. 2000. "Snowy Egret (*Egretta thula*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Petry, Maria Virginia, Vanda Simone Silva Fonseca, Lucas Krüger-Garcia, Roberta Cruz Piuco, and Jaqueline Brummelhaus. 2008. "Shearwater Diet During Migration Along the Coast of Rio Grande Do Sul, Brazil." *Marine Biology* 154 (4) (March 26): 613–621.

Pierotti, R.J., and T.P. Good. 1994. "Herring Gull (*Larus argentatus*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Pollet, Ingrid L., Dave Shutler, John Chardine, and John P. Ryder. 2012. "Ring-billed Gull (*Larus delawarensis*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Poole, A.F. 1982. "Brood Reduction in Temperate and Sub-tropical Ospreys." *Oecologia* 53: 111–119.

Powell, George V.N., and Robin D. Bjork. 1989. "Relationships Between Hydrologic Conditions and Quality and Quantity of Foraging Habitat for Roseate Spoonbills and Other Wading Birds in the C-111 Basin." *Annual Report to the South Florida Research Center, Everglades National Park, National Park Service*.

Ramo, Cristina, and Benjamin Busto. 1993. "Resource Use by Herons in a Yucatan Wetland During the Breeding Season." *The Wilson Bulletin* 105 (4): 573–586.

Rodgers, James A. Jr. 1982. "Food of Nestling Little Blue Herons on the West Coast of Florida." *Florida Field Naturalist* 10 (2): 25–44.

Rohwer, Sievert A., and Glen E. Woolfenden. 1968. "The Varied Diet of the Gull-billed Tern." *The Wilson Bulletin* 80 (3): 330–331.

Ronconi, Robert A, Peter G. Ryan, and Yan Ropert-Coudert. 2010. "Diving of Great Shearwaters (*Puffinus gravis*) in Cold and Warm Water Regions of the South Atlantic Ocean." *PloS One* 5 (11) (January): e15508.

Schlorff, R.W. 1978. "Predatory Ecology of the Great Egret at Humbolt Bay, California." In *Wading Birds*, ed. IV Sprunt, A., J.C. Ogden, and S. Winckler, 347–353. New York: National Audubon Society Research Report No. 7.

Shealer, David A. 1996. "Foraging Habitat Use and Profitability in Tropical Roseate Terns and Sandwich Terns." *The Auk* 113 (1): 209–217.

Shealer, David. 1999. "Sandwich Tern (*Thalasseus sandvicensis*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Shields, Mark. 2002. "Brown Pelican (*Pelecanus occidentalis*)." In *The Birds of North America Online*, ed. A. Poole. Ithaca: Cornell Lab of Ornithology.

Shorger, A.W. 1962. "Handbook of North American Birds." In *Handbook of North American Birds*, ed. R.S. Palmer, 280. Vol. 1. New Haven: Yale University Press.

Simersky, B. 1971. "Competition and Nesting Success of Four Species of Herons on Four Spoil Islands in the Laguna Madre." M.S. Thesis. Texas A&M University.

Simons, Theodore R, David Lee, J Christopher Haney, John Gerwin, Chris Rimmer, Jaime Collazo, Juan Klavins, et al. 2006. "Draft Status Report on the Black-capped Petrel." *U. S. Fish and Wildlife Service*.

Ueoka, Meyer L, and James R Koplin. 1973. "Foraging Behavior of Ospreys in Northwestern California." *Journal of Raptor Research* 7 (2): 32–38.

Willard, David E. 1977. "The Feeding Ecology and Behavior of Five Species of Herons in Southeastern New Jersey." *The Condor* 79: 462–470.

Audubon FLORIDA

fl.audubon.org

THE PEW CHARITABLE TRUSTS

pewtrusts.org